TITLE Optimization of Coal Particle Flow Patterns in Low NO_x Burners

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OBJECTIVE

The proposed research is directed at evaluating the effect of flame aerodynamics on NO_x emissions from coal-fired burners in an effort to develop rational design tools for optimizing low NO_x burners to the kinetic emission limit (< 0.2 lb/MMBTU). This fundamental research includes both experimental and modeling efforts being performed at the University of Arizona and at Purdue University. Experimental studies include both cold and hot flow evaluations of the following parameters: flame holder geometry, primary and secondary inlet air velocity, coal concentration in the primary air and coal particle size distribution. Hot flow experiments evaluate the effect of wall temperature on burner performance. Cold flow studies are conducted with surrogate particles. The cold flow results will aid in predicting the particle flow patterns in the hot-flow furnace, as well as to estimate the effect of flame holder geometry on the furnace flow field. The cold-flow results are compared with Fluent computational fluid dynamics model predictions and correlated with the hot-flow results with the overall goal of providing insight for novel low NO_x burner geometries.

ACCOMPLISHMENTS TO DATE

Cold-Flow Studies (Purdue University)

- Constructed a particle-laden jet flow facility to make cold flow measurements using laser Doppler velocimetry and phase Doppler particle anemometry

- Particle tracking simulations using Fluent were performed to correlate these simulations with the experimental measurements
- For a fixed solids mass flowrate of 70 micron glass beads and fixed primary nozzle Reynolds number, the effect of changes in the secondary velocity on the resulting particle flow patterns were explored.

  Results: a) As the secondary velocity increases, the turbulence level of the inner shear layer increases as evidenced by higher values of the Reynolds stress.

  b) The mean particle radial velocity increases with increasing secondary velocity due to a dragging action by the fluid phase turbulence

  c) Increasing the secondary velocity increases the axial particle velocity fluctuations

  d) Particle size measurements show an increase in the mean particle diameter between 5 and 10 primary nozzle diameters downstream as a result of small particles being ejected from the jet by large eddies. Larger particles are preferentially located in regions with high Reynolds stress
- The predictive capabilities of ad-hoc theories and CFD turbulence models for confined jet flow systems with recirculation were evaluated.

  Results: a) For the case of a single confined jet, the CFD models and the ad-hoc theories were comparable in performance for large chamber to nozzle diameter ratios (~ 30)

  b) For the case of a single confined jet, both the CFD models and the ad-hoc theories were not able to reliably predict the reattachment point for chamber to nozzle diameter ratios less than 10.

  c) For all cases, the CFD models gave improved predictions of the mass of recirculation than the ad-hoc theories.

  d) For confined double concentric jet systems, the CFD turbulence models outperformed the ad-hoc theories in terms of all features of the recirculation.

Hot-Flow Studies (The University of Arizona)

- Installed particulate collection venturi system in furnace exhaust
- Constructed water-cooled temperature and gas sampling probes. Gas sampling probes include water quench and water knockout/collection system
- Configured computer data acquisition system for monitoring wall temperatures, gas compositional data from CEM's and combustion air, furnace, hot exhaust and cooled exhaust gas temperatures
- Integrated flame safety and emergency shut-down systems for 2M furnace into existing laboratory safety systems
- Installed and integrated loss-in-weight coal feeder system into furnace control/operating system
- Initiated furnace shakedown/performance evaluations using natural gas
- Obtained stable type 0 attached flames (axial jet) at heat loads from 4 to 20 kW under both turbulent and laminar combustion air conditions

ARTICLES/PRESENTATIONS

S. Budilarto, C. Blake-Powell, and J. Sinclair, "Prediction of Recirculating Flow in Confined Jets for Combustion Systems", 1999 Spring AFRC Meeting, Tucson, AZ, March 1999.

S. Budilarto, C. Blake-Powell, and J. Sinclair, "Prediction of Recirculating Flow in Confined Jets for Combustion Systems", 1999 AIChE Annual Meeting, Dallas, TX, November 1999.

S. Budilarto and J. Sinclair, "Velocity Ratio Effect on Gas and Particle Motion in a Confined Coaxial Jet", Midwestern Annual Fluid Mechanics Conference, Rochester, IN, April 2000.

S. Budilarto and J. Sinclair, "Velocity Ratio Effect on Gas and Particle Motion in a Confined Coaxial Jet", 2000 AIChE Annual Meeting, Los Angeles, CA, November 2000 (to be given)